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IBAHRS - AN INFLATABLE RESTRAINT SYSTEM FOR HELICOPTER AIRCREWMEMBERS

James R. McElhenney
Aircraft and Crew Systems Technology Directorate
NAVAL AIR DEVELOPMENT CENTER
Warminster, Pennsylvania 18974

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Inflatable Body and Head Restraint System (IBAHRS) is a new concept in helicopter aircrew restraint which utilizes inflatable airbag technology for increased crash protection. IBAHRS uses a conventional helicopter restraint harness with bladders attached and neatly folded to the underside of the shoulder harness. Inside each bladder is a small solid propellant gas generator. During a crash, an omnidirection crash sensor remotely located on the aircraft, sends an electric current to a squib in each gas

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generator. This action inflates the bladders with a nontoxic gas in under twenty milliseconds, and removes the slack in the restraint. This tightening action couples the occupant more firmly to the seat and reduces the dynamic overshoot which results with a loose restraint during a crash. The wearer's strike potential with cockpit objects is reduced as is strap loading on his torso when the inflated bladders are compressed during crash loading. A reduction of strap load concentration on the body is achieved because of the increased bearing surface provided when the restraint is inflated. An appendage of the upper restraint inflates under the wearer's chin to reduce potential injury due to violent forward head motion which occurs during a crash. A crotch strap is provided to prevent submaring by the seat occupant.

This report describes the current configuration of the advanced development model of IBAHRS and details its principle of operation.

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INTRODUCTION

BACKROUND

The Seating and Escape Branch of the Aircraft and Crew Systems Technology Directorate at the Naval Air Development Center (NAVAIRDEVCEN) has developed a new restraint system for helicopter aircrewmembers. Known as the Inflatable Body and Head Restraint System (IBAHRS), it incorporates automotive airbag technology into the conventional helicopter restraint to provice increased crash protection to the wearer. In-house design, fabrication and testing of IBAHRS has established the feasibility of such a system and its superiority to the conventional restraint. Figure 1 shows the configuration of this early model.

Inflation of the system automatically pretensions the straps which forces the occupant back in his seat. This action moderates the dynamic overshoot effect which results during a crash with a loosely worn restraint. It also restricts the motion of the wearer, lessening his chance of striking cockpit objects. Strap loading on the wearer is diminished when the inflated restraint is compressed during crash loading. A reduction of strap load concentration on the body is achieved because of the increased bearing surface provided when the restraint is inflated. An appendage of the upper restraint inflates under the wearer's chin to attenuate the violent forward head motion which occurs during a crash. A crotch strap is provided to prevent submarining by the seat occupant.

A total of twenty-five dynamic tests of this device was conducted on the NAVAIRDEVCEN horizontal accelerator. The results of this program and a detailed description of the feasibility model of IBAHRS is contained in reference (a). In addition to these tests, IBAHRS was tested in a full scale U.S.Army crash test of a CH-47A helicopter conducted by the U.S. Army Applied Technology

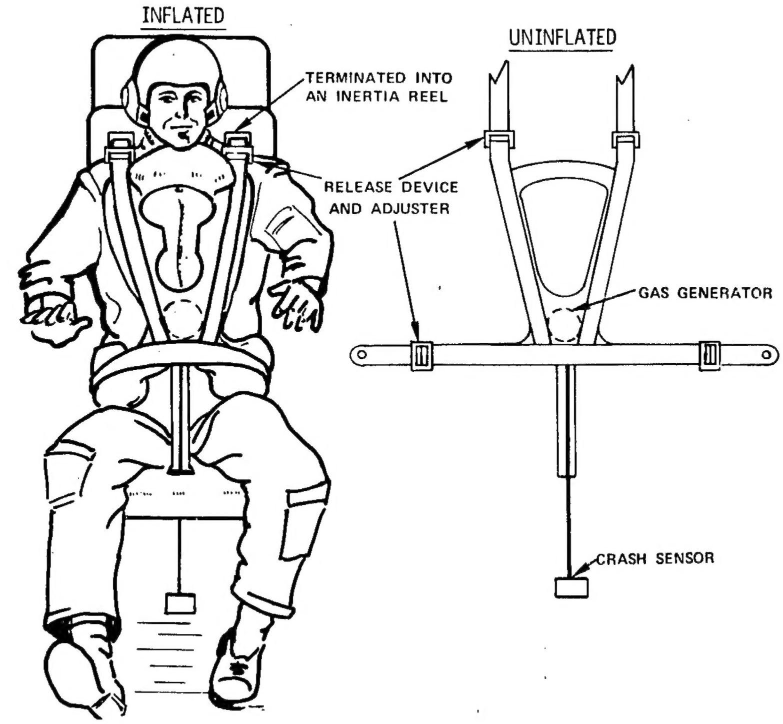


FIGURE 1 - Feasibility model of the IBAHRS

Laboratory (ATL), Fort Eustis, Virginia. This test program has been reported in reference (b).

After establishing the feasibility of the system, the next step was refinement of the design for user acceptability and the development of an omnidirectional crash sensor which will trigger inflation of the system in a crash. The U.S. Army Applied Technology Laboratory joined NAVAIRDEVCEN in the former effort and the new IBAHRS was included as one of a number of restraints dynamically tested by ATL at the Federal Aviation Administration's Civil Aeromedical Institute's (CAMI) horizontal sled facility. This test program is reported in reference (c).

The new design incorporated inflatable bladders with the conventional MS16069 shoulder harness and provided a solid propellant gas generator in each bladder to accomplish inflation. The design was modified for the CAMI sled tests and is shown in figure 2 with the bladders unfolded. A crotch strap was included in this design as shown in figure 3. Additional test specimens were fabricated using a MIL-S-58095 rotary buckle restraint. This configuration is shown in figures 4 and 5 and is the system to be used in future test program. Figure 6 shows a seated occupant wearing the IBAHRS in both the stowed and the inflated condition.

D E S C R I P T I O N

CURRENT CONFIGURATION-ADVANCED DEVELOPMENT MODEL

The prototype IBAHRS has three main subassemblies: (a) the harness/bladder, (b) the solid propellant gas generator or inflator and (c) the omnidirectional crash sensor system. Figure 7 is an illustration of the various parts showing the inflators located inside the bladders and the sensor hookup to the aircraft's electrical system.

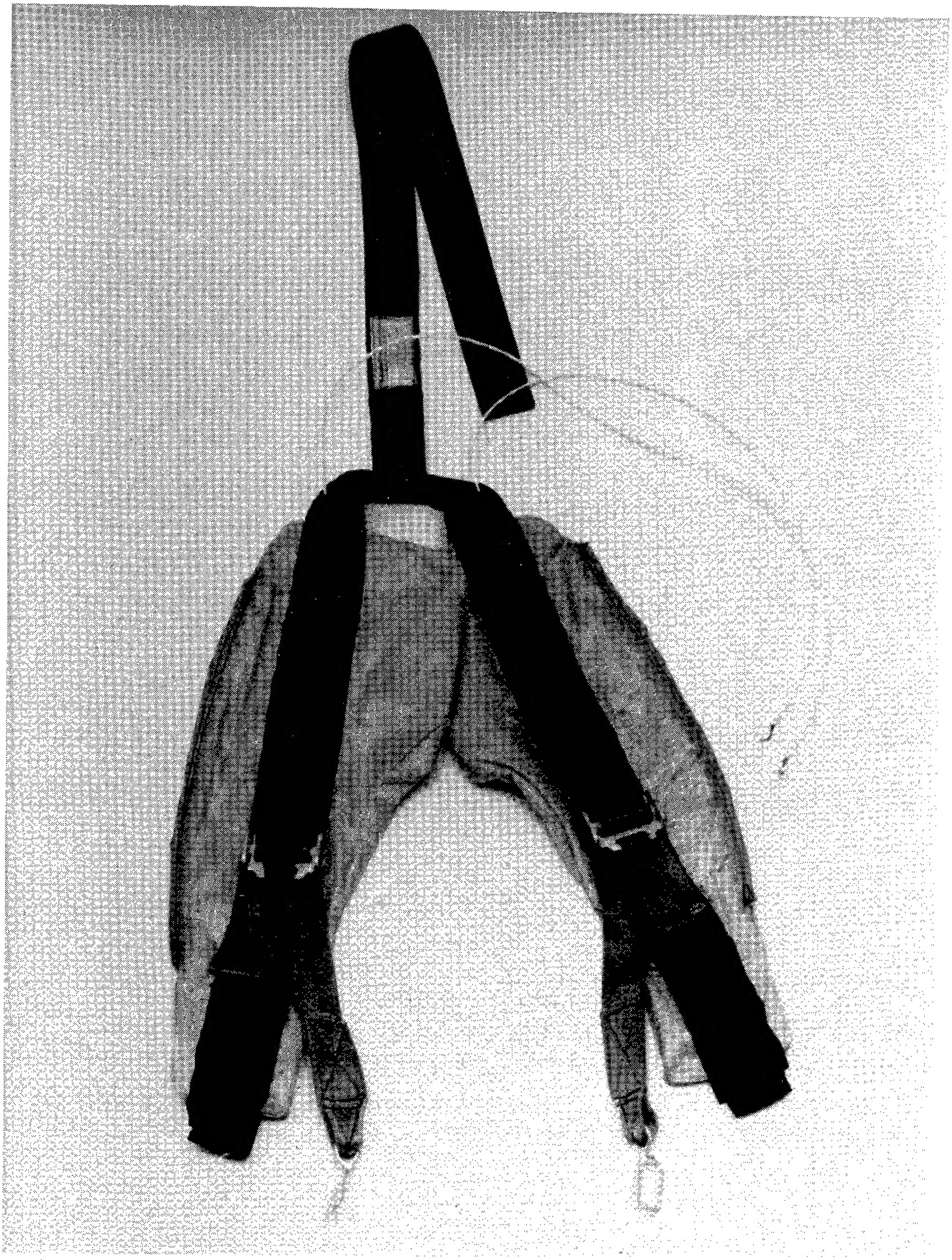


FIGURE 2 - IBAHRS with MS16069 hardware -bladders unfurled

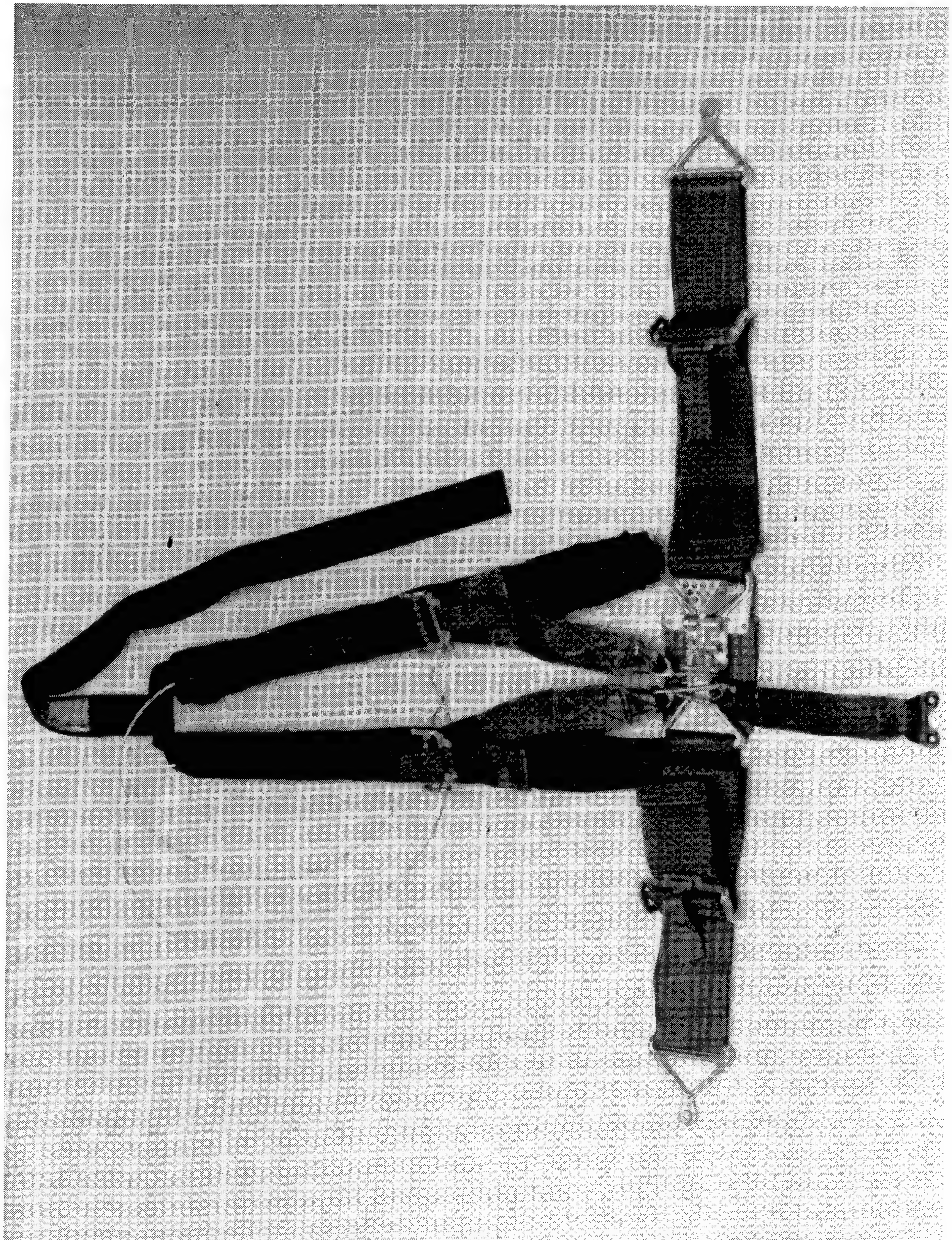


FIGURE 3 - IBAHRS in stowed position with lap belt and tie-down strap

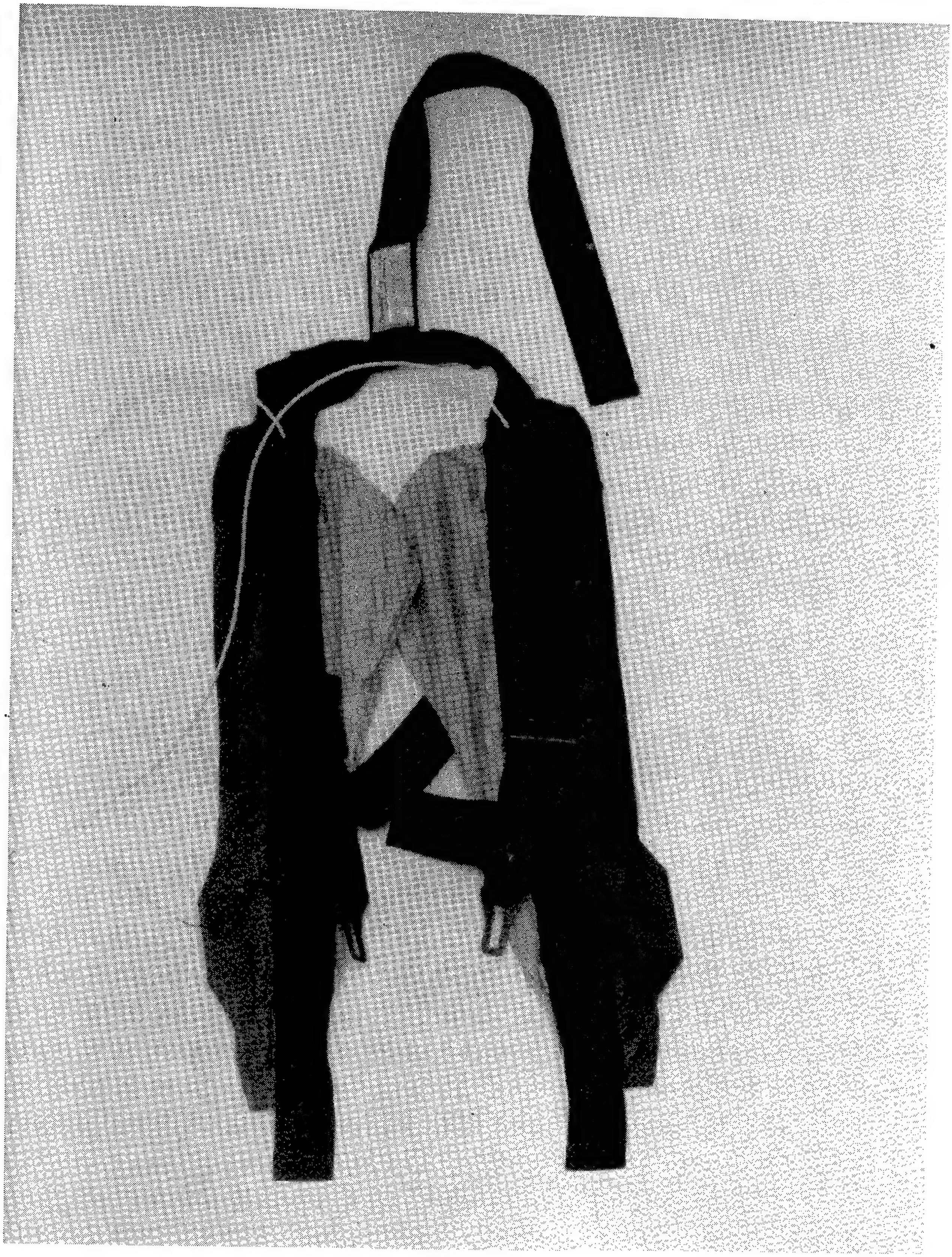


FIGURE 4 - IBAHRS with MIL-S-58095 shoulder harness showing bladders and cover

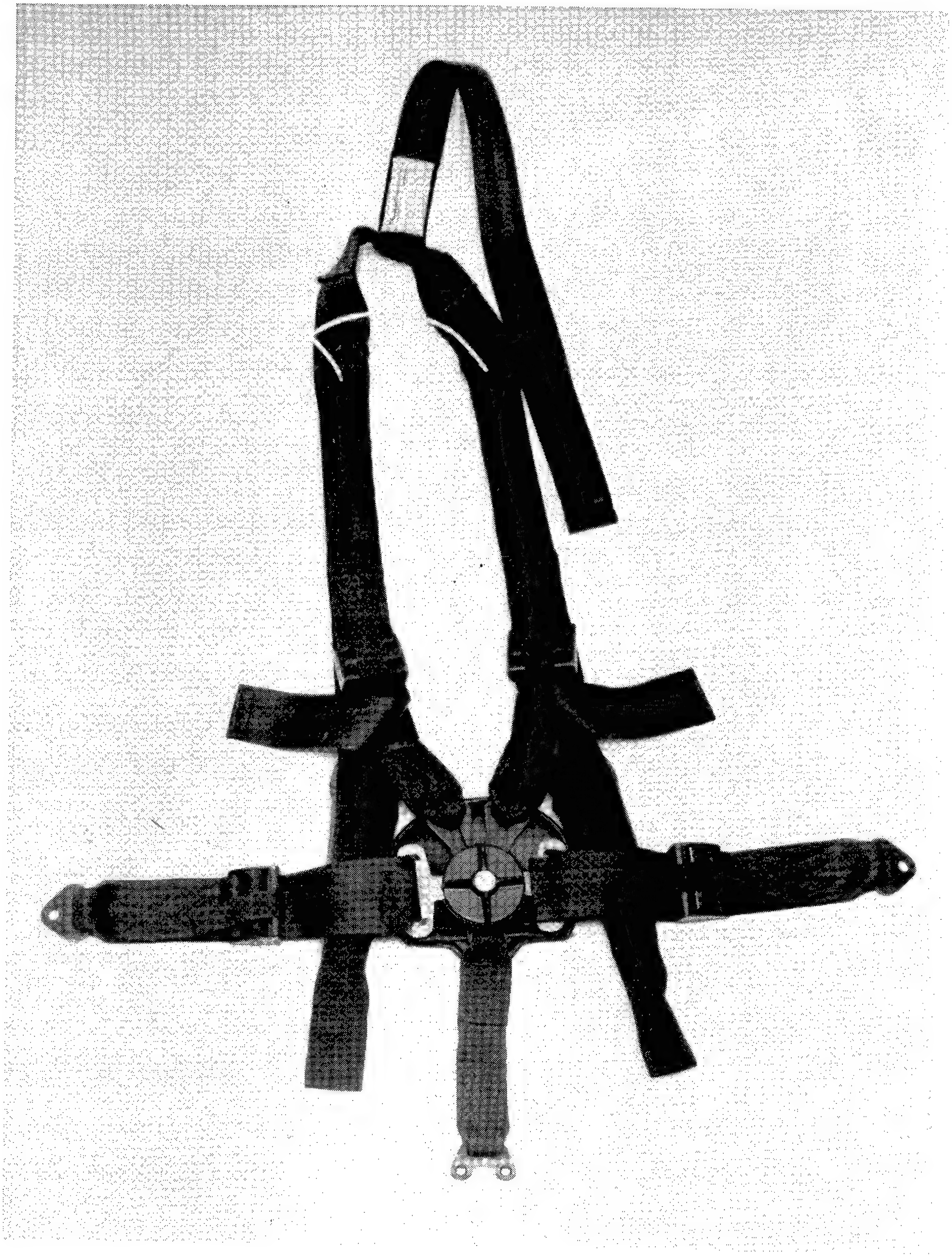


FIGURE 5 - IBAHRS with MIL-S-58095 restraint - bladders stowed

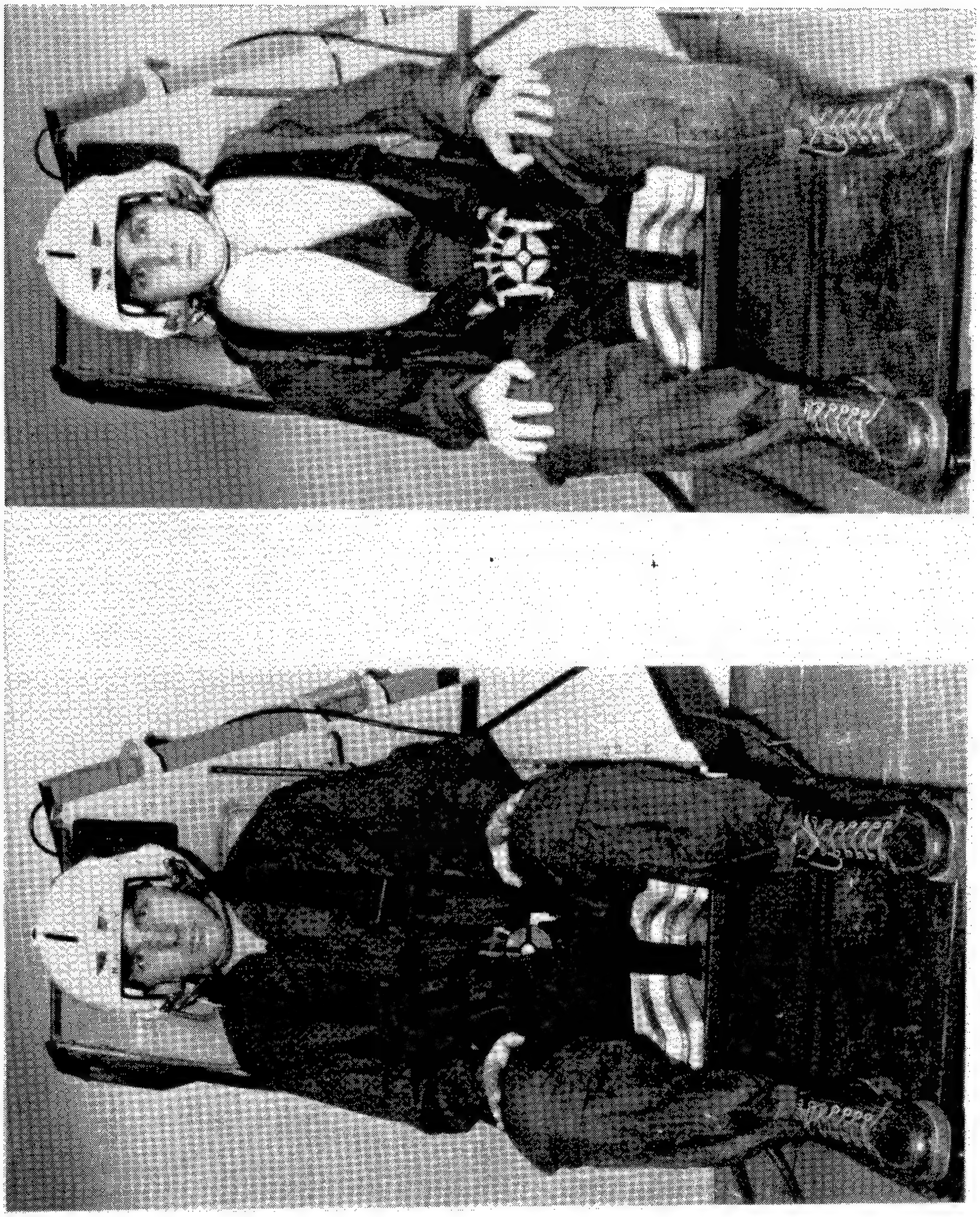


FIGURE 6 - Seated occupant wearing IBAHRS

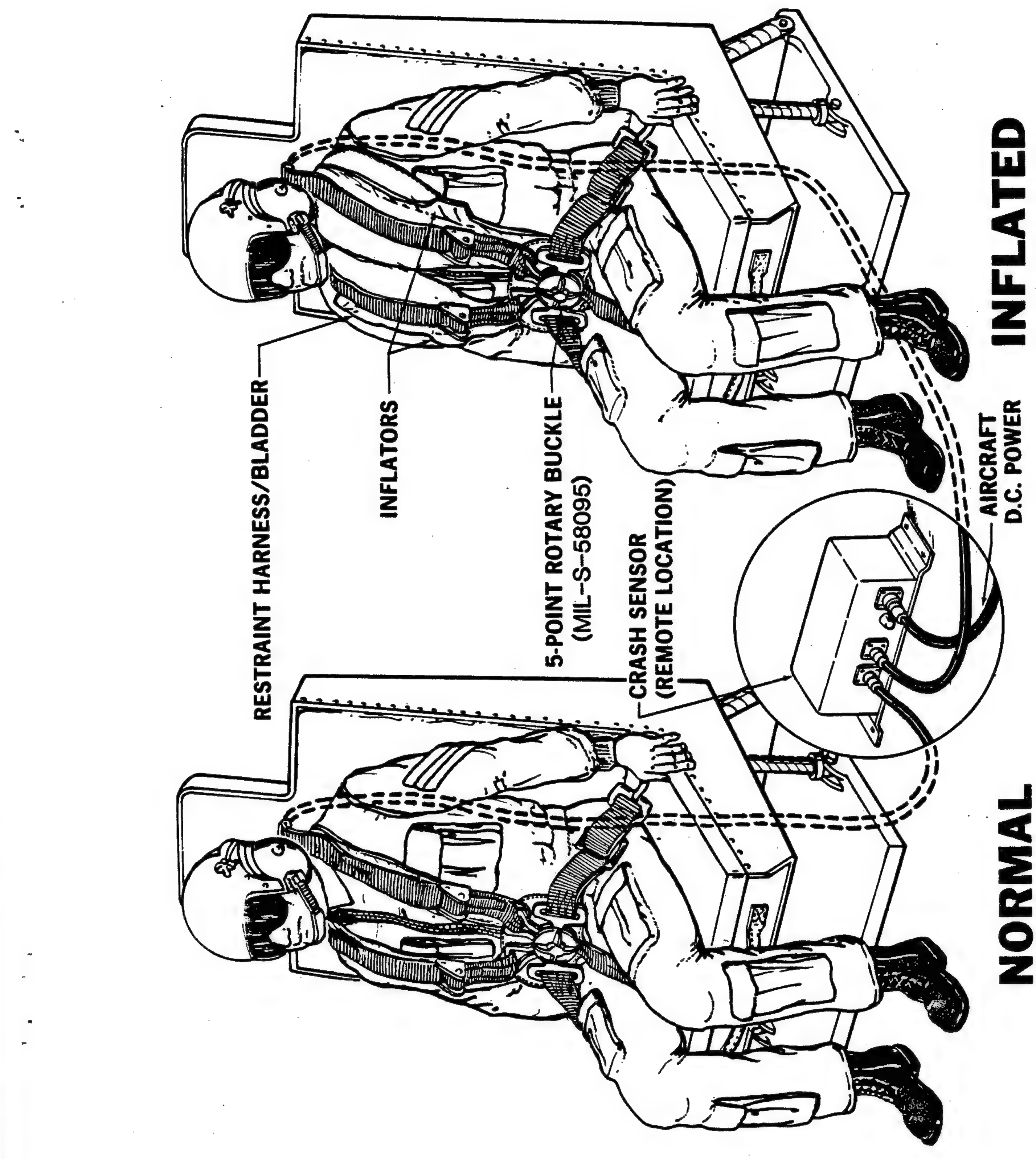


FIGURE 7 - IBAHRS installation in helicopter

When a crash is detected by the sensor, a switch closes allowing current to flow from the storage capacitor in the sensor to the gas generators located indide the bladders. This action activates the pyrotechnic gas generators and inflates the bladders in less than twenty milliseconds with a nontoxic gas.

Harness/Bladder Assembly

The restraint harness currently being used for the IBAHRS is a modified MIL-S-58095 five point restraint. To the underside of each of the shoulder straps of this restraint, a bladder of neoprene coated nylon is securely attached as shown in figure 4. The bladder is semiporous and allows the gas to escape slowly from the bladders following inflation. This action coupled with the natural cooling of the warm gas relieves the tightening effect of the inflated restraint after the crash. The use of a nonporous bag with a small pressure relief valve to achieve the same result is being investigated. During normal use, the bladders are folded and stowed in a nylon cover held fast to the restraint webbing by Velcro strips. The restraint with its bladders stowed is shown in figure 5. Positioned inside the lower portion of each bladder is the small pyrotechnic gas generator.

Solid Propellant Gas Generator

The solid propellant gas generator shown in figures 8 and 9 was designed and fabricated by Thiokol/Wasatch Division of Brigham City, Utah under NAVAIRDEVCEN contract N62269-77-C-0025. It is slightly smaller than a cigarette pack and weighs five ounces. The housing of each generator is made from a solid block of aluminum having three cylindrical cavities in a side-by-side parallel arrangement. The central cavity retains an electrical squib and a pyrotechnic material (igniter booster) in tandem. The two adjacent cavities contain gas generant material in the form of pellets. The walls between the cylindrical chambers have perforations so that hot gases from the ignited

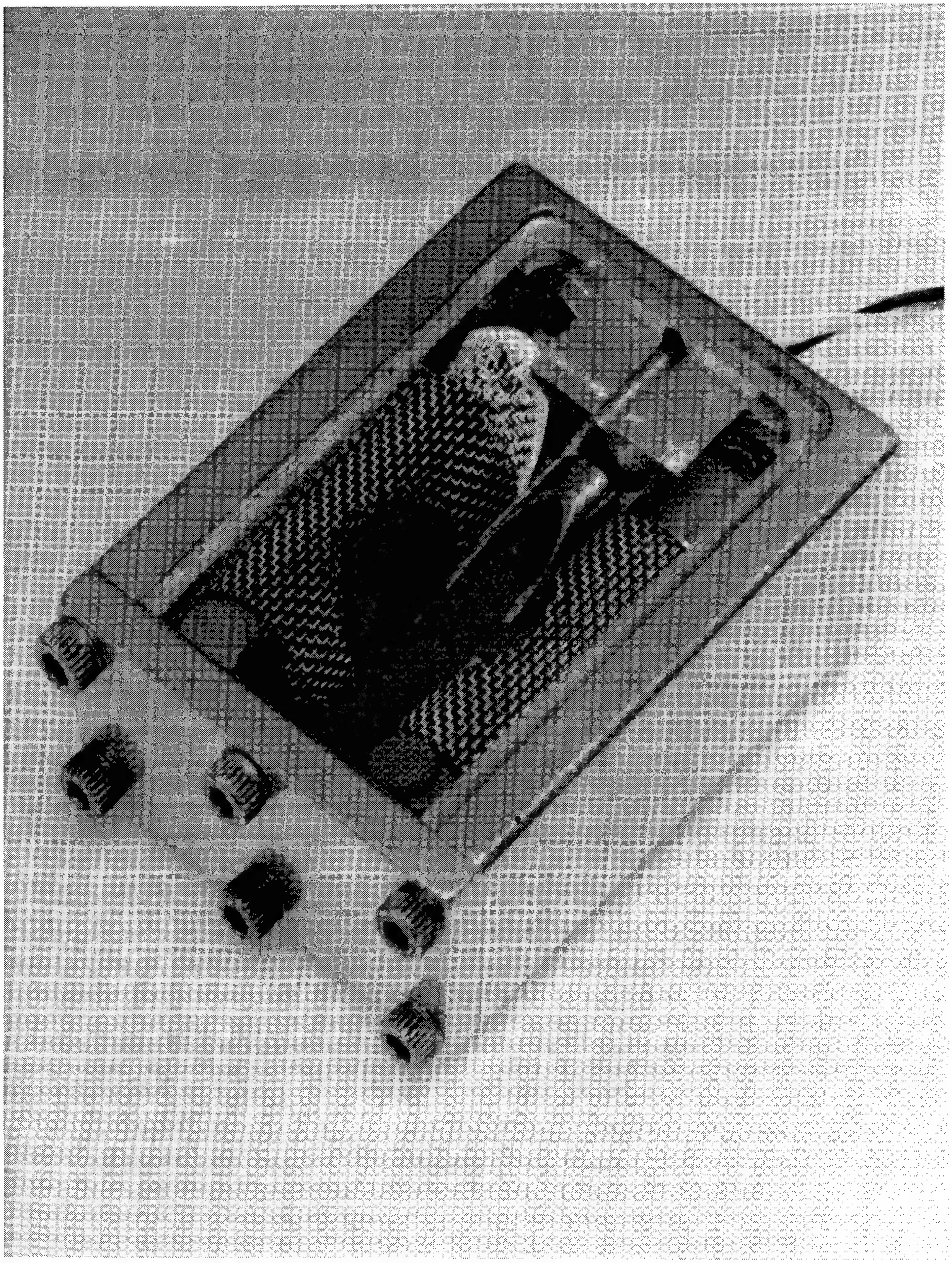


FIGURE 8 - Cutaway view of the IBAHRS solid propellant gas generator

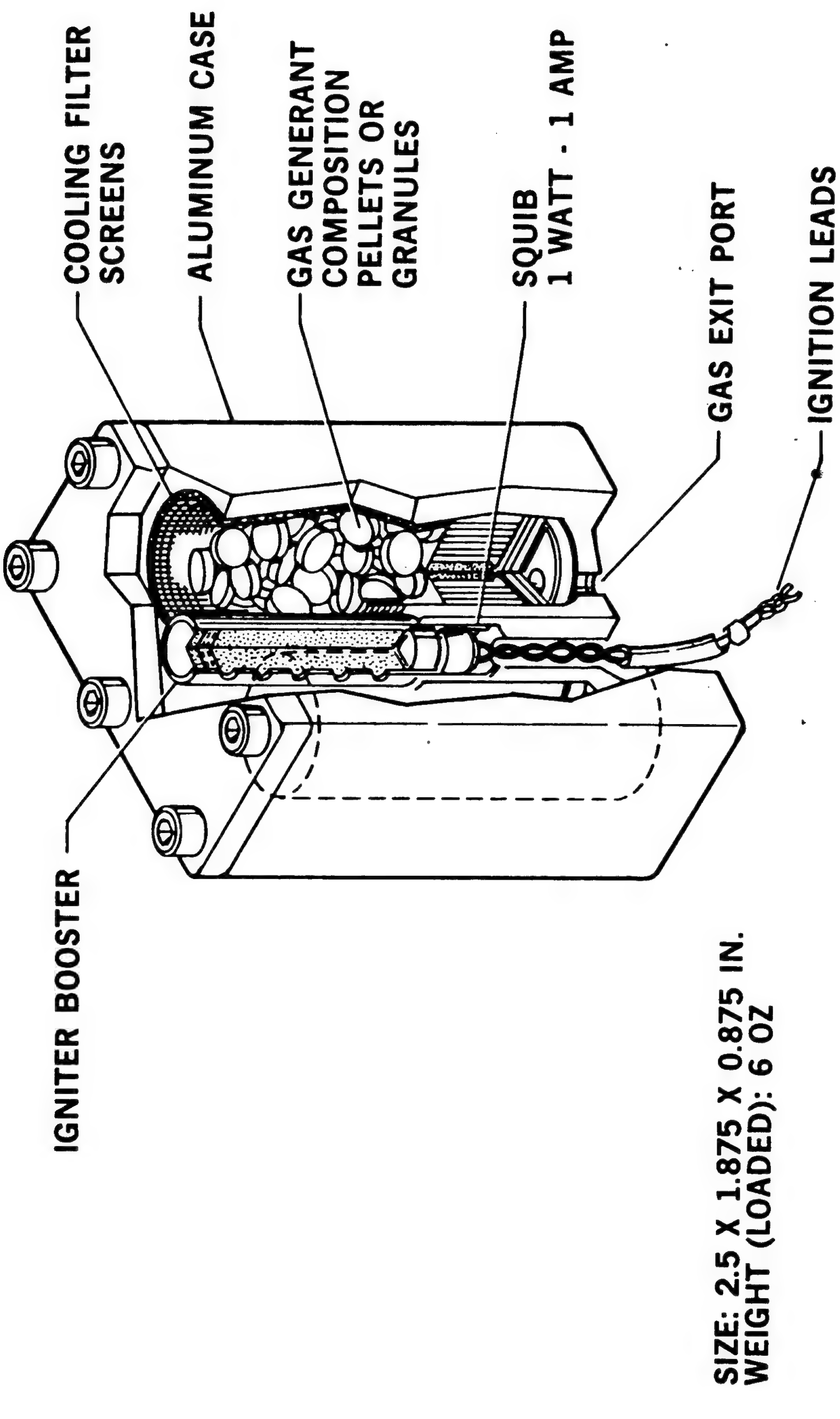


FIGURE 9 - IBAHRS solid propellant gas generator

squib and igniter booster can pass through the perforations and ignite the gas generator. The open ends of the three cavities are closed by an end plate mounted to the housing by screws. The screws also function as the means for mounting the gas generator to a bracket which secures the inflator to the bladder material.

Each of the opposite ends of the chambers has a small orifice for exhausting gases from the gas generant into the air bag. Spirally wrapped cooling screens, fine and coarse filter screens and a layer of pH adjusting material are all interposed between the gas generant and each exhaust orifice, and occupy the end of each cylindrical chamber opposite the end plate. Figure 10 is a flow chart which describes the inflation process.

The electric squib has a no-fire rating of one amp D.C. for five minutes or one watt for five minutes. Its recommended minimum fire current is 3.4 amps for 5 milliseconds. The autoignition temperature is in excess of 450°F and the operating temperatures are from -80°F to +350°F.

Omnidirectional Crash Sensor System

Technar Incorporated of Arcadia, California designed and fabricated the IBAHRS crash sensor system under NAVAIRDEVCEN contract N62269-79-C-0735. The crash sensor system is used to rapidly detect the occurance of a helicopter crash and to provide a circuit closure and an electrical energy source for firing the squibs in the IBAHRS gas generators. It also monitors the crash sensing system through a diagnostic circuit and provides an indication of a system failure.

Figures 11 and 12 show the single package which houses the following major components:

a) Vertical Sensor

b) Horizontal Sensor

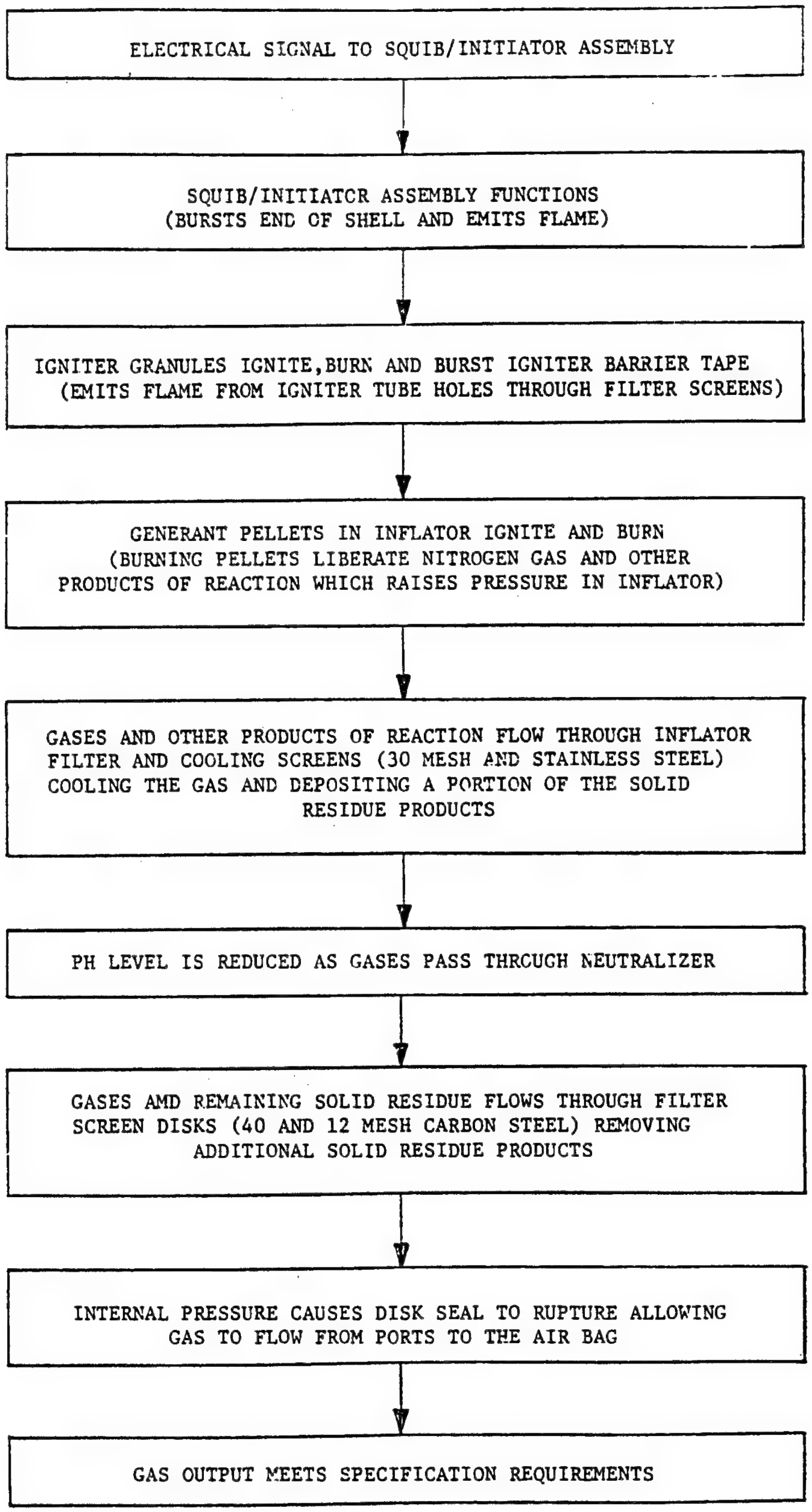


FIGURE 10 - IBAHRS inflation sequence flow diagram

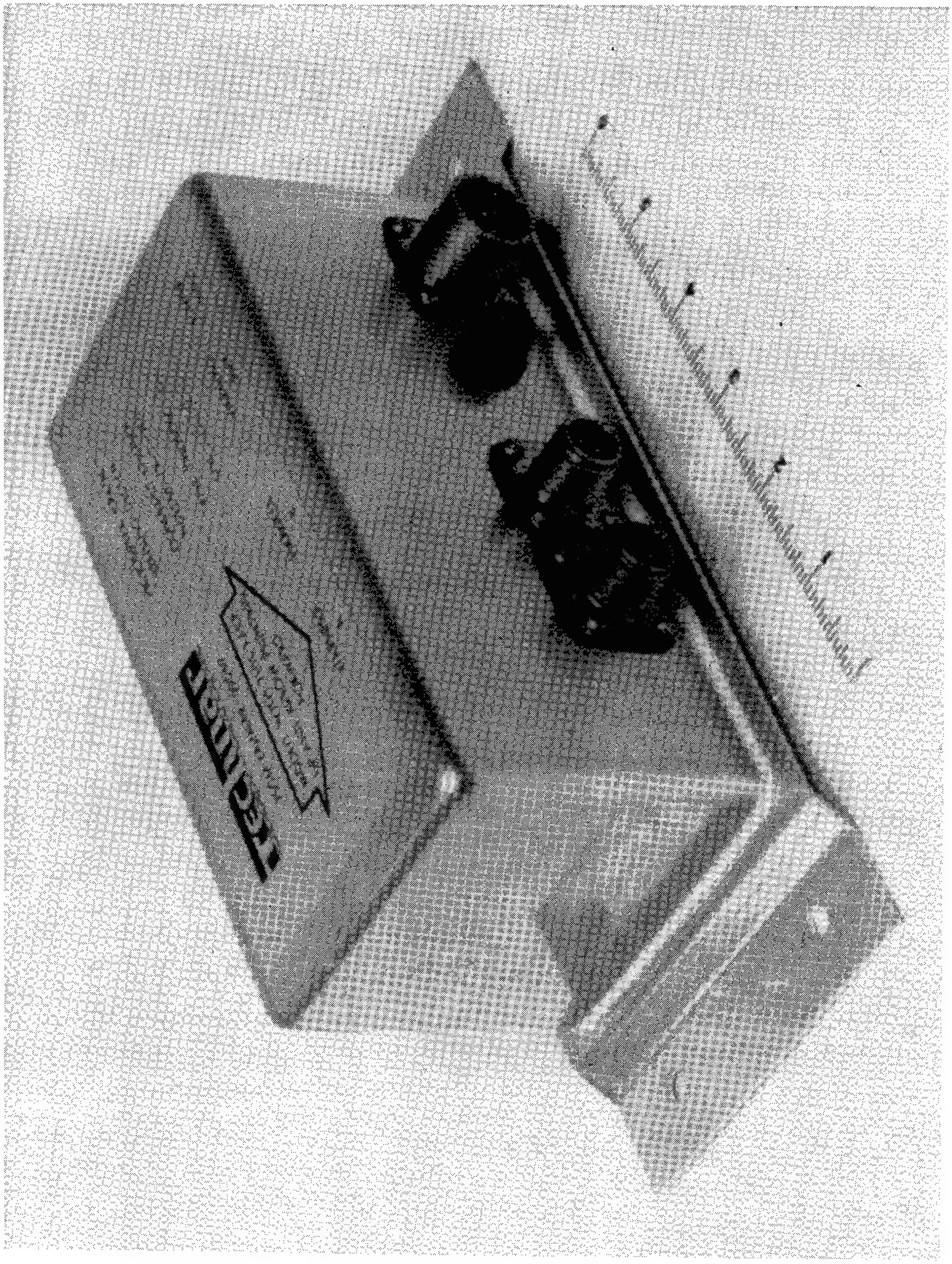


FIGURE 11 - Omnidirectional crash sensor system

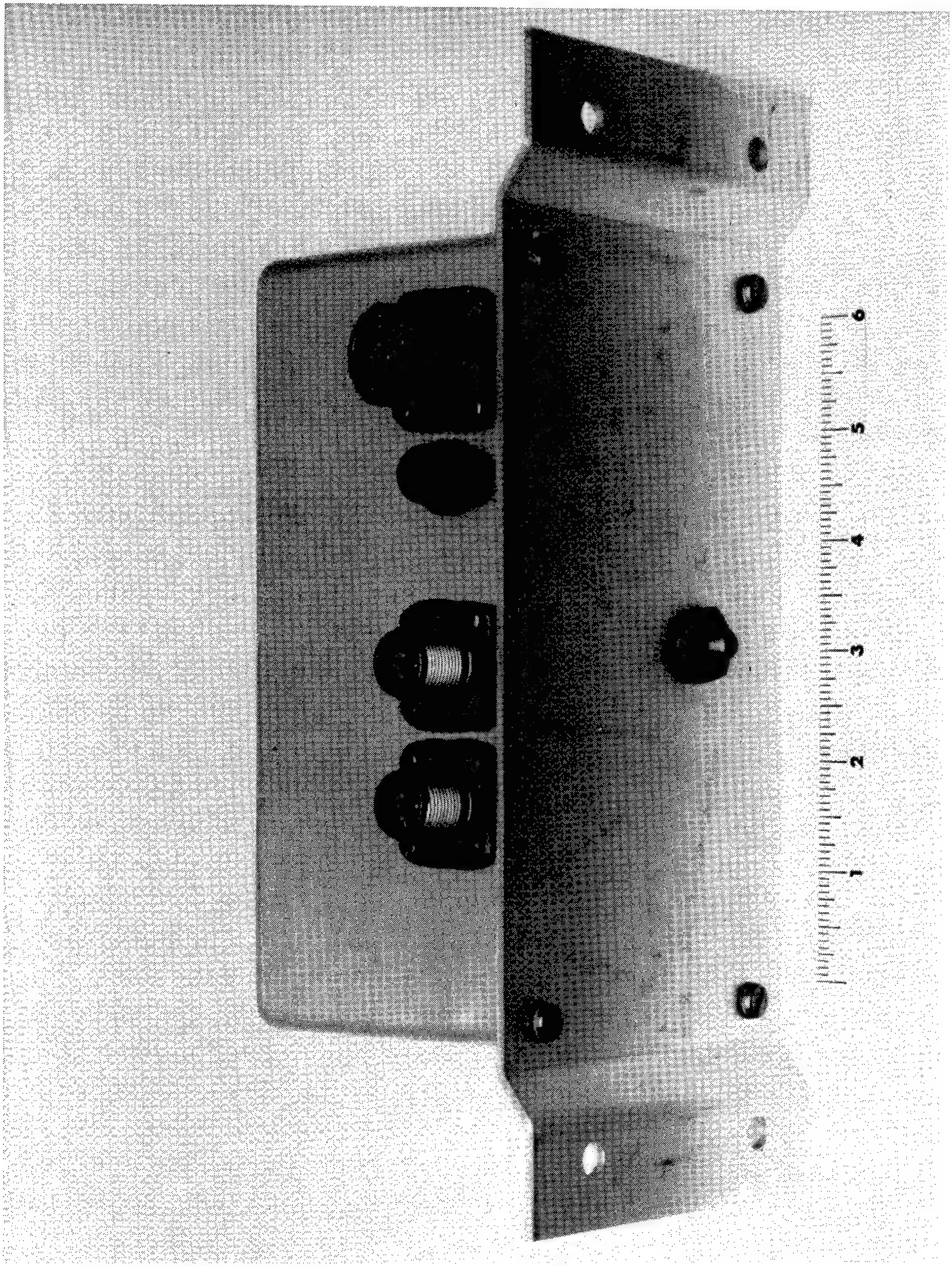


FIGURE 12 - Omnidirectional crash sensor system showing the mounting switch

c) Diagnostic Circuit

d) Storage Capacitor

e) Diagnostic Warning Light

f) Mounting Switch

g) Power Input Connector

h) IBAHRS Harness Output Connectors (2)

Figure 13 shows the internal arrangement of the components and figure 14 indicates the physical dimensions of the sensor.

1. Vertical Sensor

Shown in Figure 15 is the gas damped, piston-in-tube, vertical sensor which responds to accelerations in the vertical direction. Three compression springs are employed to achieve the necessary spring rate and contact closures. The net rate of the normally closed contact spring and bias spring determines the rate. The mass is initially held at the top against the central step by a net force of 2 g's including the effect of gravity.

Acceleration causes the piston to move down, opening the normally closed contact spring at its free length shortly before the normally open contact spring bridges the contacts. The mass can overtravel by compressing the normally open contact spring until stopped by the central protrusion of the mass. The contact force thus goes up during overtravel.

As the piston moves, air is pumped both through the hole and around the circumference from the forward ullage to the aft ullage. The compression of the gas provides an additional spring rate.

Calibration of the sensor is accomplished by varying the diameter of the small axial hole. In practice, it has been found that within a given lot of honed tubes and ground masses a single hole size is adequate.

The electrical path when the sensor is at rest includes the bias spring,

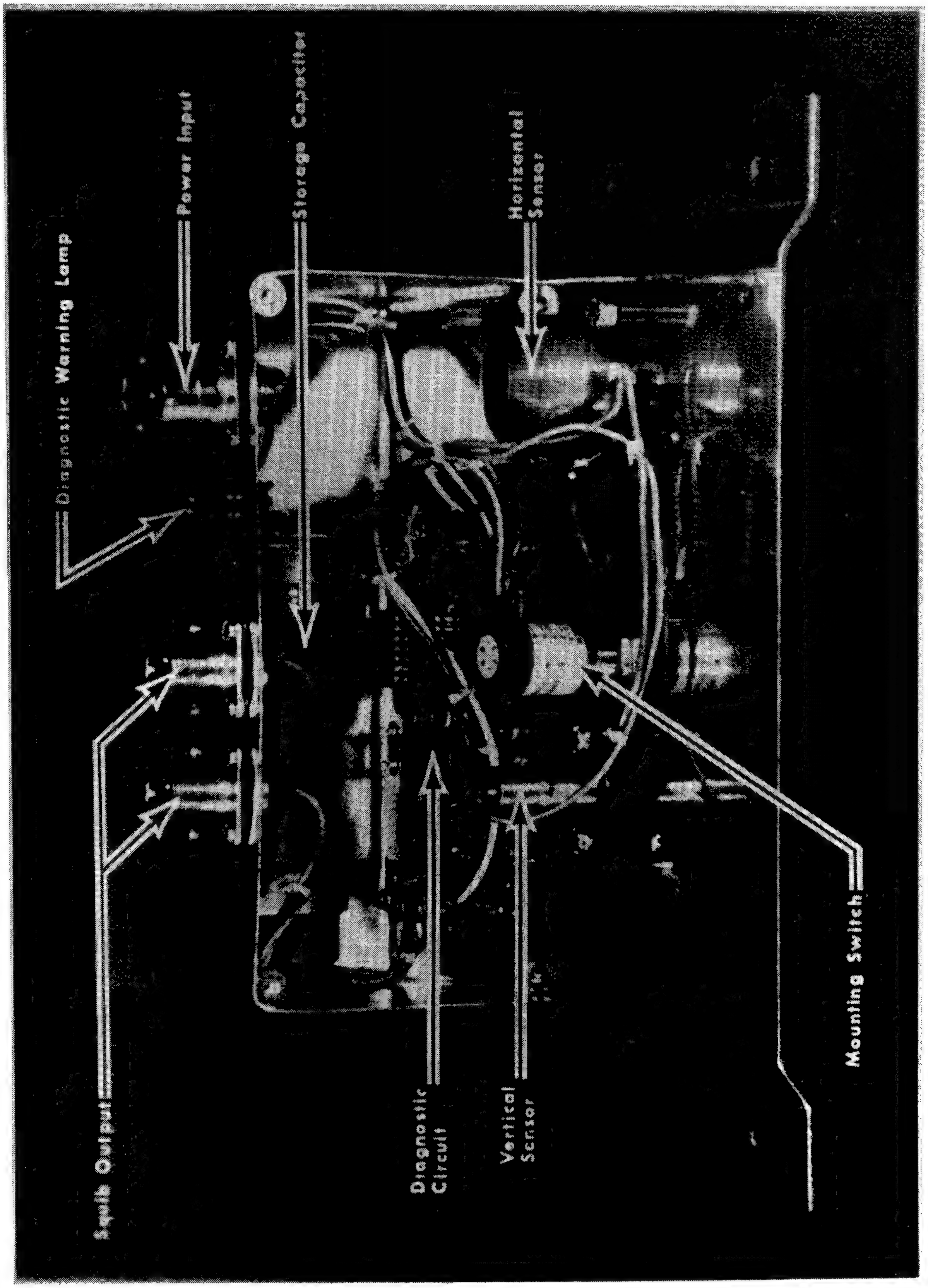
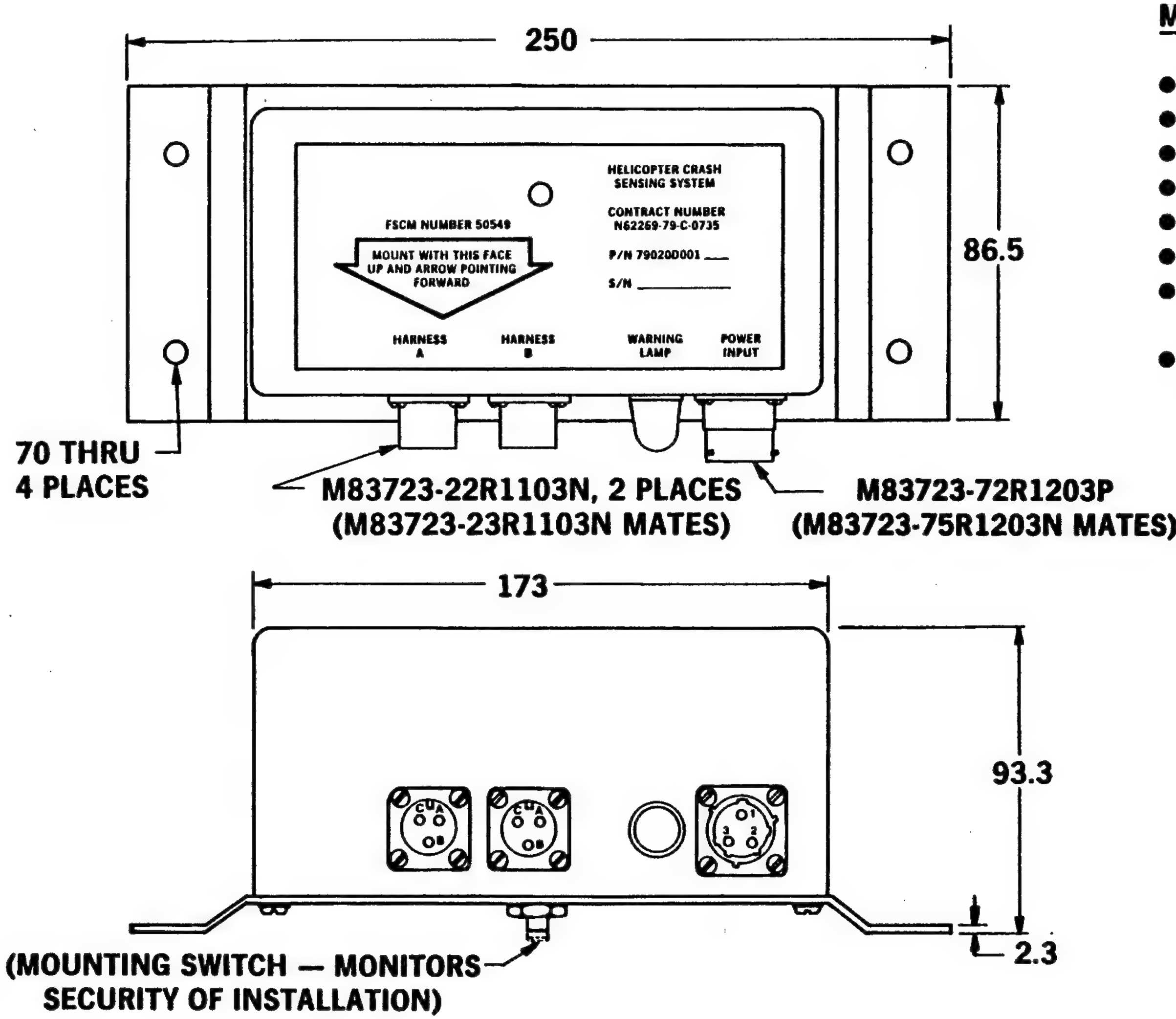


FIGURE 13 - Internal arrangement of sensor system



MAJOR COMPONENTS

- VERTICAL SENSOR
- HORIZONTAL SENSOR
- MOUNTING SWITCH
- DIAGNOSTIC CIRCUIT BOARD
- STORAGE CAPACITOR
- WARNING LIGHT
- INPUT (POWER) AND OUTPUT (SQUIB) CONNECTORS
- CASE FOR THE ABOVE WITH MOUNTING PROVISIONS

UNIT WEIGHT 3.25 POUNDS

DIMENSIONS IN MILIMETERS

FIGURE 14 - Omnidirectional crash sensor system showing dimensions

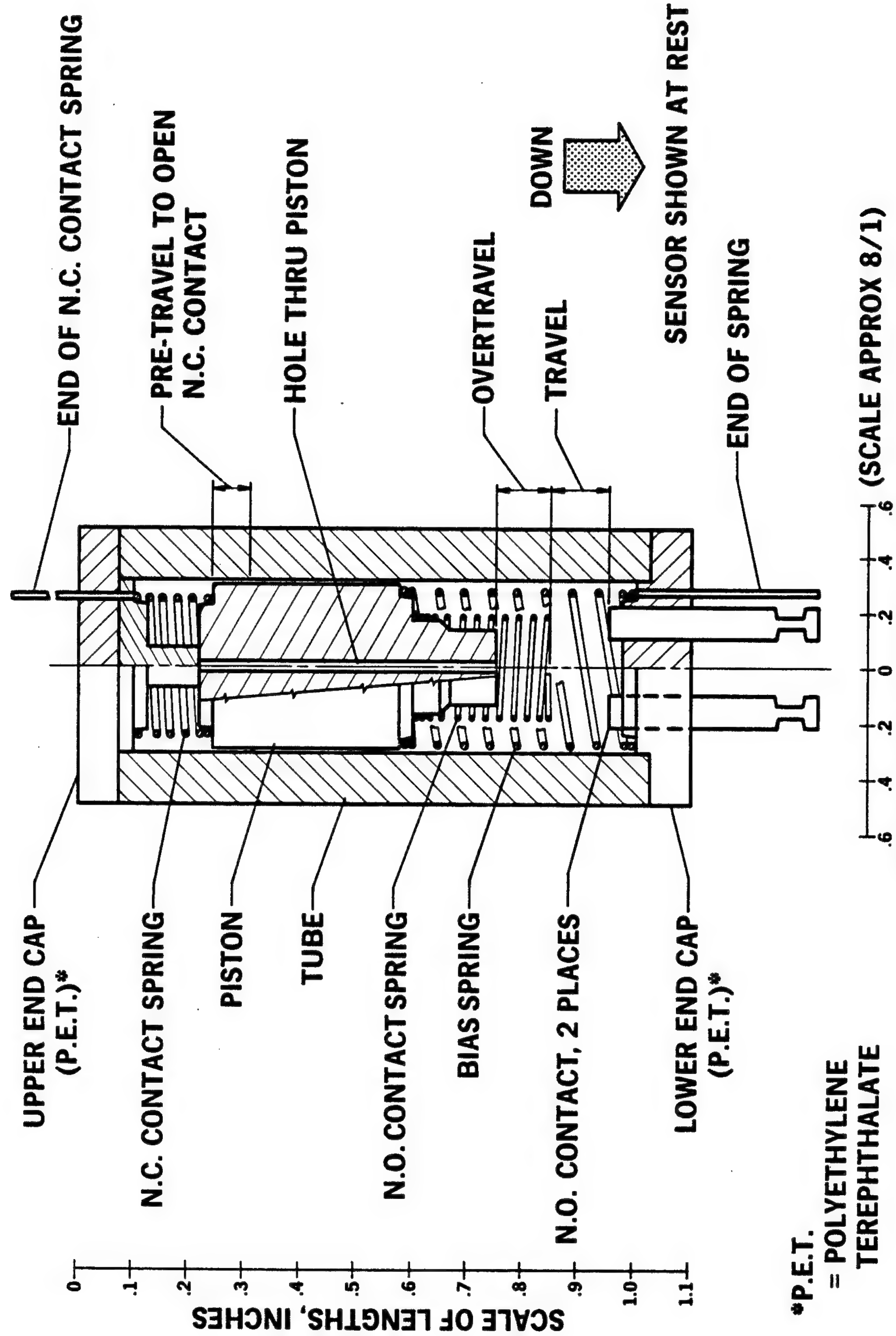


FIGURE 15 - Gas damped vertical crash sensor

the sensing mass, and the normally closed contact spring. Thus the normally closed circuit resistance is relatively high--about one half to one ohm. The firing circuit resistance is quite low because only one half of the coil of the normally open contact spring is part of the firing circuit.

The acceleration threshold for the vertical sensor is illustrated in figure 16 and indicates the "no fire" and "must fire" regions of the acceleration-time curve.

2. Horizontal Sensor

Figure 17 shows the spring-mass horizontal sensor which responds, with essential equal sensitivity, to accelerations from any direction of the horizontal plane.

The cylindrical sensing mass is loaded downward against the base of the cone-shaped housing by the conical spring. Sufficient acceleration from any direction in the horizontal plane causes the mass to pivot at a point at the outer edge of its base. As the mass tilts, the protrusion from its base moves upward and loads the common contact leaf less. At the firing angle, the normally closed contacts have already opened, and normally open contacts just close. The contact gap is such that under vibration, causing the mass to move but not fire, the normally closed contacts remain closed. The mass can actually tilt through an angle greater than the firing angle. This overtravel allows an increase in the normally open contact force and decouples the mass from the common contact leaf.

Calibration is accomplished by adjusting the set screw in the protrusion at the base of the mass. Its position changes the angle at which contact transfer takes place.

Vibration damping is achieved by bonding cryogenic silicone rubber

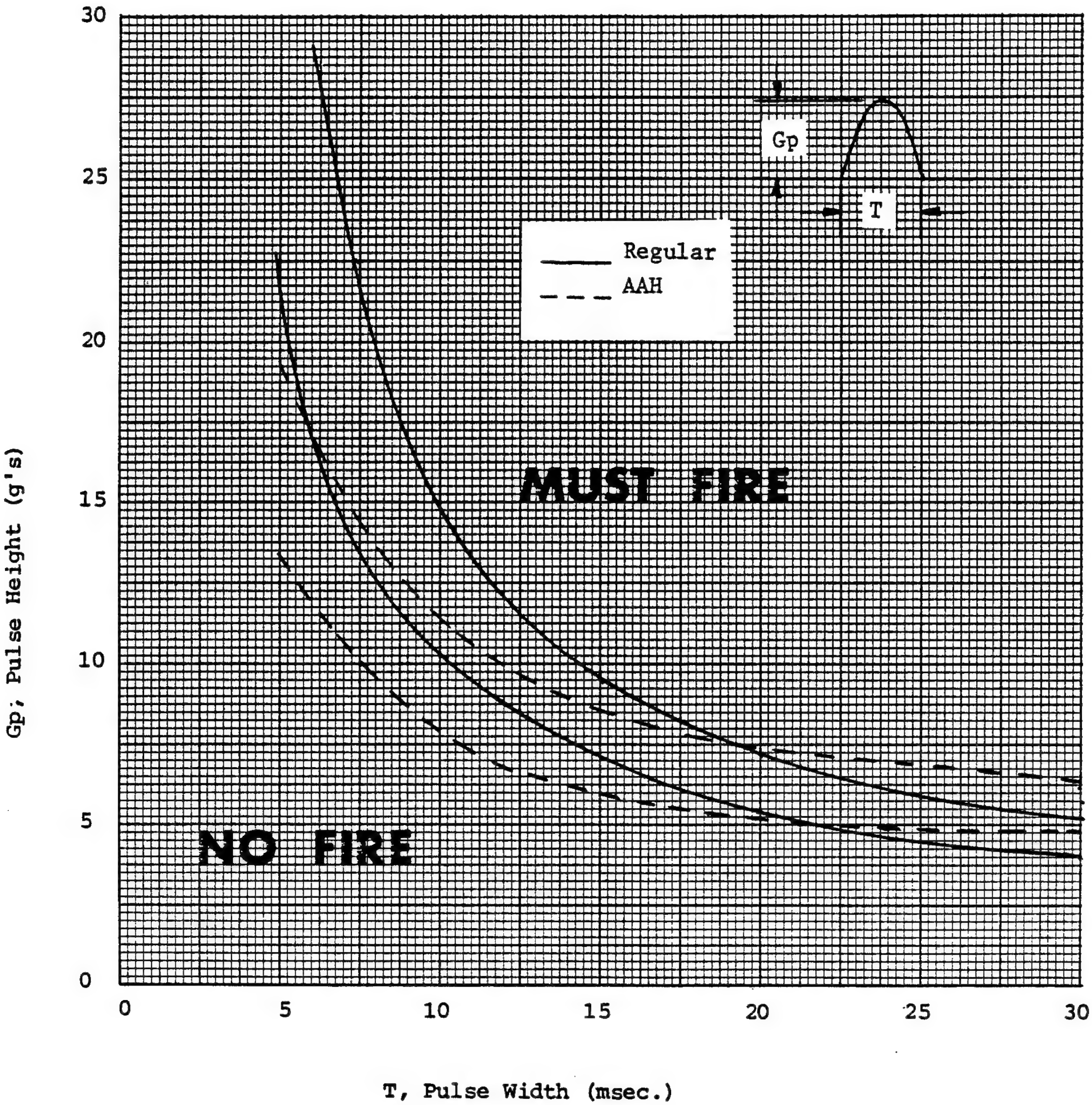


FIGURE 16 - Vertical sensor threshold requirements

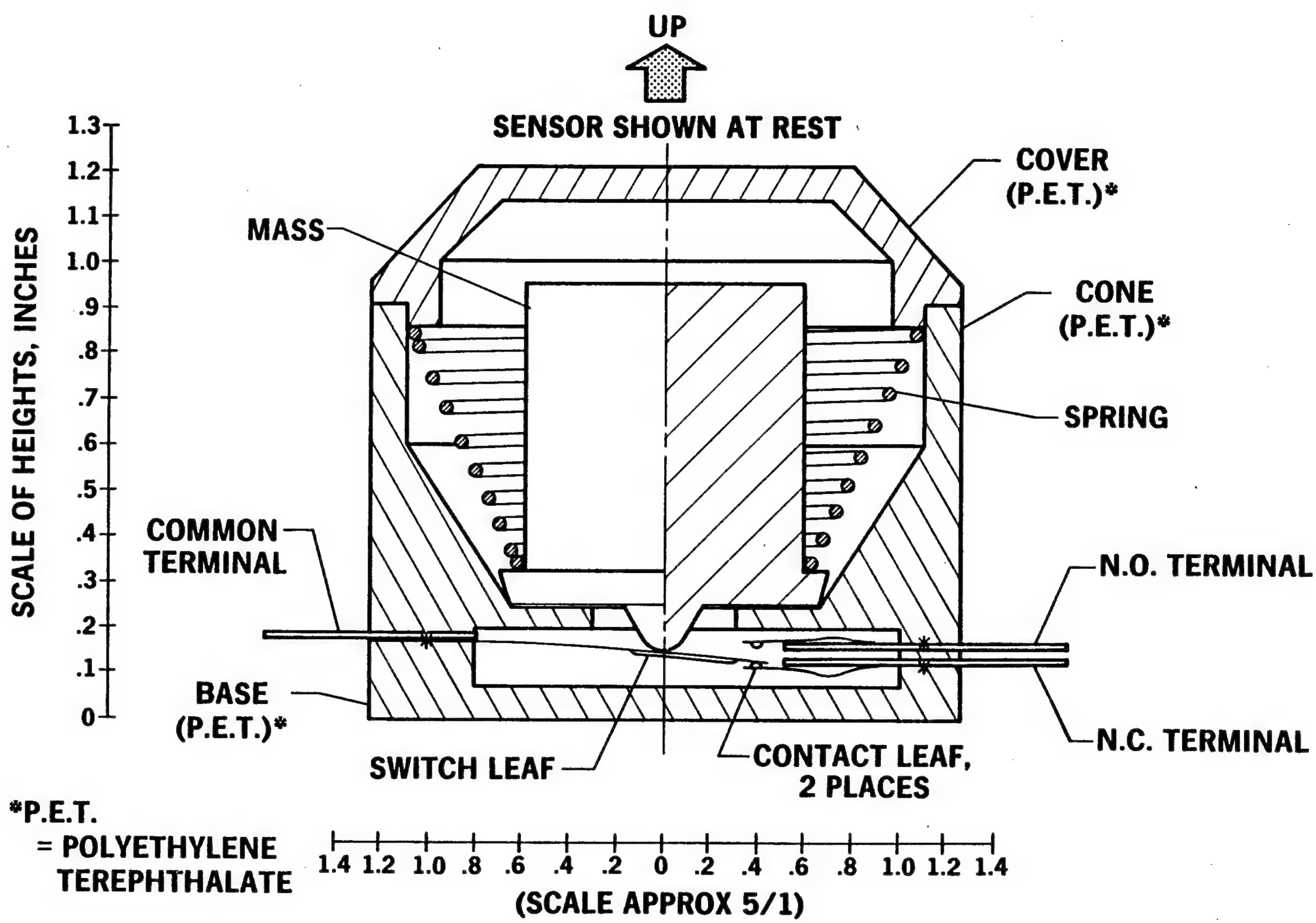


FIGURE 17 - Spring damped omnidirectional (horizontal) sensor

to the base of the mass. This effectively reduces sensitivity to vibration.

Figure 18 is the acceleration threshold for the horizontal sensor.

3. Diagnostic Circuit

The electronic diagram of the diagnostic circuit is shown in Figure 19. The diagnostic circuit portion of the sensor system is used to verify that the entire system is working properly. It monitors the sensors, their secure mounting and the circuit itself, and provides an indication of any failure discovered via the diagnostic warning lamp. It is capable of detecting the following system failures.

a) Squibs open

b) Mounting switch open

c) Sensing mass not in "at rest" position

d) Sensing mass in firing position

e) Electrical leakage inside sensor

f) Storage capacitor shorted

g) Power supply below 12.5 volts

h) Warning light burned out

i) Failures of semiconductors in the diagnostic circuit

Reference (d) provides a more detailed description of the diagnostic circuit.

4. Storage Capacitor

The storage capacitor is an electrolytic type rated at 18,000 μf,40 VDC and conforms to MIL-C-39018. It is connected to the aircraft 28 volt DC power supply through the sensor power connector. In the event of aircraft power failure, the capacitor is designed to retain, for five seconds, sufficient charge to fire two IBAHRS. This feature keeps the system active should a slight delay occur before the emergency DC power becomes available.

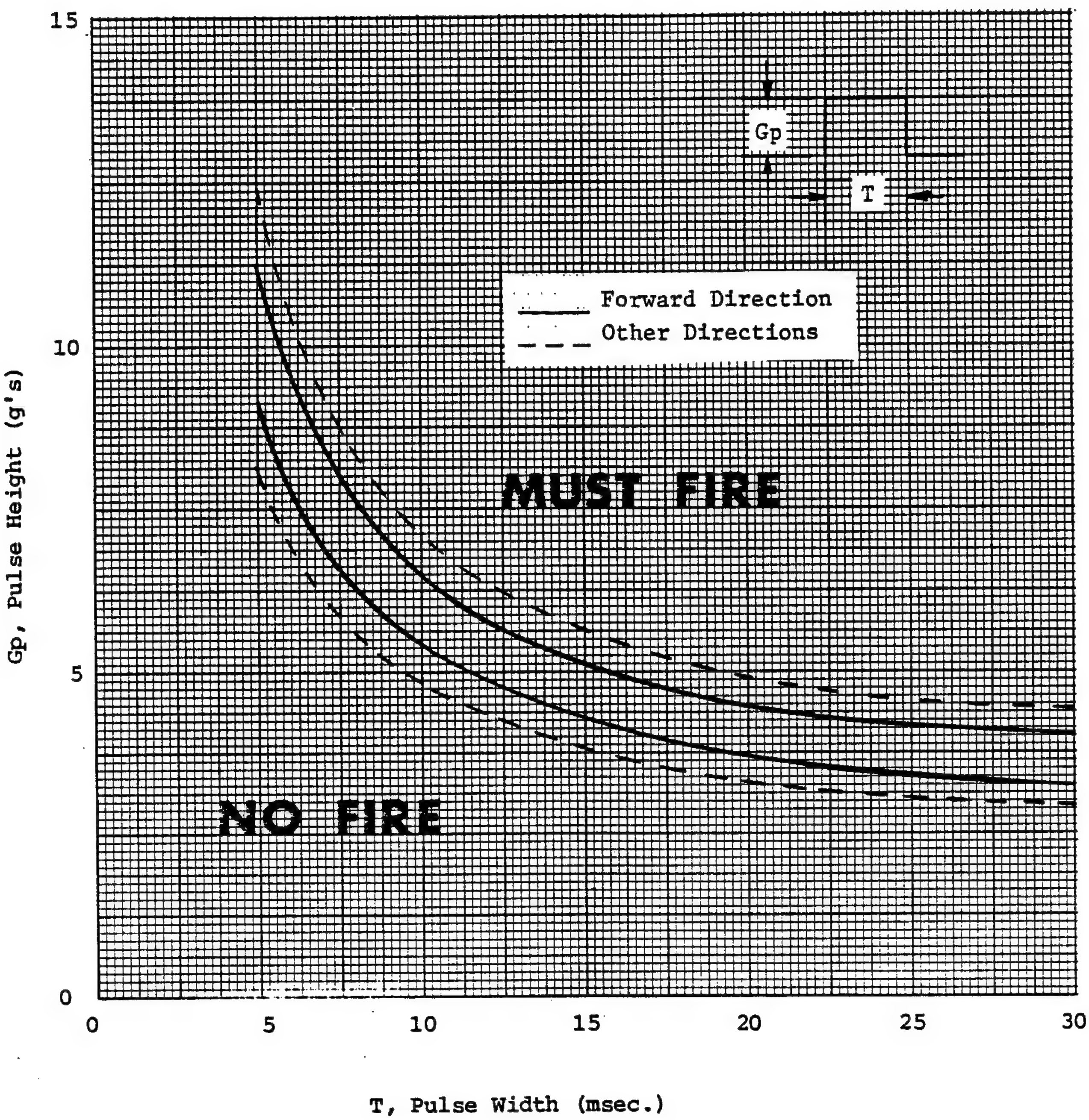


FIGURE 18 - Horizontal sensor threshold requirements

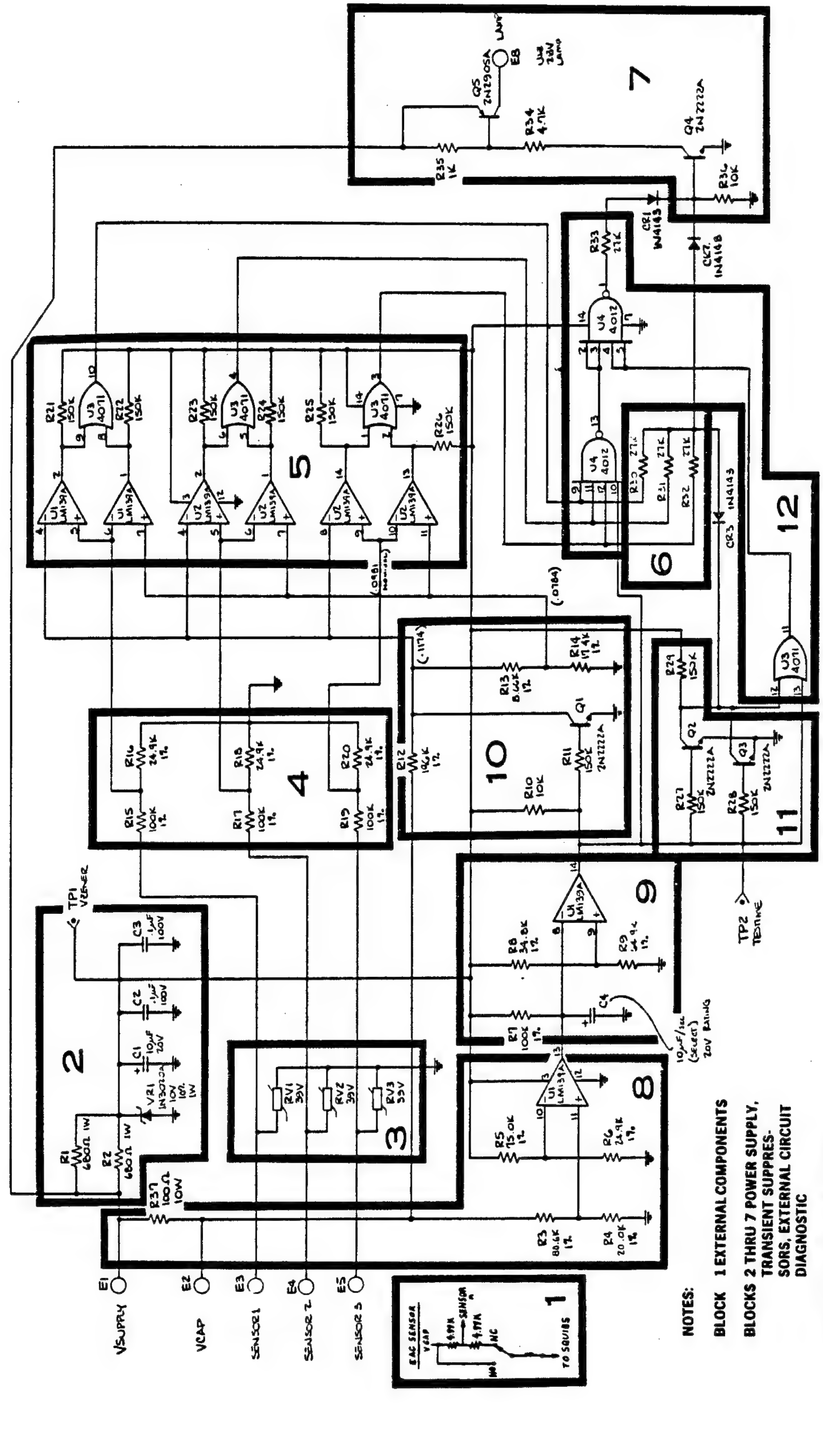


FIGURE 19 - Crash sensor system diagnostic circuit

Emergency DC power is supplied to the aircraft electrical system from an 18- volt battery. This ability of the capacitor plus the requirement that it operates at -65 F increases the physical size of the capacitor and accounts for the bulk of the crash sensor volume.

5. Diagnostic Warning Light

In order to check the electronic circuit itself upon power up, the warning light is made to turn on briefly if there are no detected malfunctions. The time interval during which the light is on during power up is called test time and is about 5 seconds in duration. The truth table for the diagnostic function is thus:

	Light On	Light Off
Test Time	OK	Failure
Later	Failure	OK

Currently, the warning light is mounted on the sensor case. It's likely that the sensor will be located in the aircraft where the light cannot be seen, so it will be the necessary to replace the existing lamp with another output connector so that the lamp itself can be readily observed.

6. Mounting Switch

The mounting switch is attached to the bottom of the sensor case as shown in figures 12 and 13. Its purpose is to provide an alert through the warning light if the sensor is not securely mounted to the aircraft structure which could cause inadvertant actuation of IBAHRS.

7. Input and Output Connectors

Aircraft power is supplied to the sensor system through the power connector while the output connectors allow two IBAHRS units to operate from the sensor. Power input, and output to the squibs is to be accomplished through the connectors with pairs of 16 gage, shielded wire.

CURRENT STATUS AND FUTURE ACTIVITIES

The IBAHRS program is now a joint Army/Navy effort sponsored by the U.S. Army Aviation Research and Development Command and Naval Air Systems Command with NAVAIRDEVCEN as lead technical laboratory. The Army's immediate interest is to install IBAHRS in their attack helicopters to prevent aircrewmembers from striking cockpit objects by limiting upper torso motion. A similar need for IBAHRS exists in Army/Marine Corps AH-1 helicopters because of the close proximity of the crew to instrument panel, cyclic stick, glare shield and weapons sighting systems.

A prototype configuration has been installed on a Hughes AH-64 helicopter at Yuma, Arizona for OT-1 flight test evaluations. Of particular interest during the operational flight testing is the sensitivity of the crash sensor circuit to the vibration/flight-loads environment of an attack helicopter. Human factors engineering evaluations are scheduled to be conducted by the Army at the Aberdeen Proving Grounds,Maryland. The pyrotechnic gas generator has passed Design Verification Tests (DVT) and is now undergoung qualification testing to meet approval for service use (ASU) requirements. A validation-in-process review (VAL IPR) has been scheduled for Februrary 1983 to determine the readiness of the IBAHRS for phasing into the production schedule of the AH-64.

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